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POTATO SPRAYING AND DUSTING EXPERIMENTS 1926 TO 1928

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BULLETIN 352

POTATO SPRAYING AND DUSTING EXPERIMENTS 1926 TO 1928.[1]

REINER BONDE, DONALD FOLSOM[2], AND E. R. TOBEY[3]

SUMMARY

(1) In 1926 a yield increase resulted from homemade Bordeaux mixture in each of two experimental fields but was not consistent enough to be significant. The extent of this yield increase was determined largely by the control of late blight and by the time of the killing frost. A single application in one plot happened to give the best results. Two infected plants initiated infection areas that spread throughout a field.

In 1927 the yield increase from Bordeaux spraying was highly significant and again was due to the control of late blight, which was severe. Some increase was obtained from colloidal copper having one-third the copper strength of the Bordeaux. Copper-lime dust and sodium-fluosilicate dust controlled late blight. Apparently the cause of late blight can be brought by the air from other plots or fields. Diseased plots in a field decrease the efficiency of a fungicide in the same field.

In 1928, with late blight very severe, similar good control and large yield increases were secured with the homemade Bordeaux mixture, half-copper-strength colloidal-copper spray, copper-lime dust, commercial dried and powdered Bordeaux used as a spray, and the last used as a dust. A new commercial copper spray ("Oxo Bordeaux") also controlled late blight in 1928, while a sodium-fluosilicate-lime spray did not.

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[1]See Bulletin 334 for experiments 1921 to 1925 and for summary of work up to 1921. A publication giving general practical recommendations is the Maine Agricultural Extension Circular 85, Bordeaux mixture, by A. K. Gardner.

[2]The second author's efforts were restricted to help in yield measurements and sorting in storage, literature review, and preparation of bulletin manuscript.

[3]The third author made the chemical analyses.

In all three years, very little rot developed in storage even in stock from check (untreated) plots. Also insects, and other diseases besides late blight, were not important.

(2) The gain in yield from spraying varies greatly with the season, averaging during our 13 years' tests about 8 per cent of the average check yield of 117 barrels or 323 bushels. No method is known of safely modifying the standard schedule to fit the variations of the season.

(3) In five years' comparison in Aroostook County, there was slightly more gain from using copper-lime dust than from Bordeaux spraying, both averaging about 5 per cent over the check yield of 121 barrels or 332 bushels. A review of reports from other regions shows that many conditions influence the results, and that the plot technique in many tests is inadequate, but that there is apparent a tendency for copper-lime dust to be less effective than Bordeaux mixture against flea-beetles, leafhoppers, and tipburn.

(4) A vine-protector device reduced injury from sprayer wheels, resulting in a significant increase in yield of 7 barrels or 19 bushels an acre, or a gain of about 5 per cent. Proper precautions and procedure are necessary for securing such benefits.

(5) The vigor of seed stock was not increased by spraying the parent plants.

(6) A delay in beginning the season's dusting or spraying can increase yield but the probability of such increase at present is uncertain.

(7) Leaf samples taken from the 1924, 1925, and 1928 tests and analyzed for copper showed two or three times as much copper accumulating with standard Bordeaux as with other materials including dusts, even when the effectiveness and yield increases were the same.

(8) In Green Mountains, mild mosaic increased susceptibility to late-blight foliage injury.

(9) In 1927 about 66 per cent of shipped stock developed rot in transit before the middle of September, but only about 3 per cent after that. Much of this could have been expected from the conditions existing during digging.

(10) Tuber rotting by late blight is not necessarily proportional to foliage injury by the same disease, but varies with soil

type and other conditions. Under some conditions rotting may be increased by spraying.

(11) For certain obvious reasons, much commercial (growers') spraying and dusting lack effectiveness. This could be corrected. An effective simple substitute for Bordeaux mixture is needed.

(12) Under conditions like those in the experimental fields, the average expected gain from using Bordeaux mixture would probably give a profit but not the expected gain from certain other materials including copper-lime dust. Gains would vary greatly with the differences in conditions of commercial fields, and are generally greater in other parts of this country.

(13) Experimental data can not foretell closely the probable effects of potato spraying and dusting in any one season or in any one field. The greatest value of experimental data probably is in giving to growers and extension experts, suggestions as to what can occur in commercial fields, and in explaining what does occur there.

REASONS FOR EXPERIMENTING

Aroostook County produces most of the potato crop of Maine which is grown exposed to a combination of northern and seaboard conditions not found elsewhere. These climatic differences require that the problem of controlling foliage diseases be studied through tests made in the State, with emphasis on experiments in Aroostook County.

Our last report on potato spraying and dusting experiments (*15*)[4] showed among other things that (1) the profits from spraying in Aroostook County are not as great as in some regions, and should be increased if possible through more economical and less injurious methods; (2) copper-lime dusting can be as effective as spraying but at the same rate of copper consumption is more costly due to the expense of factory-mixed materials; and (3) results can vary from one location to another in the same season.

In the course of the next three seasons (1926-1928) it seemed desirable to test a vine protector, the omission of the early applications of dust and spray, and the merits of several new spray

[4]Numbers in italics refer to Literature Cited at the end of this bulletin.

and dust materials. Incidentally some attention was given also to the test of a claim that spraying increased the seed vigor, to the comparison of copper content of sprayed and dusted foliage, and to the influence of certain conditions on late blight both with and without the use of fungicides.

EFFECTS OF SPRAYING AND DUSTING

EXPERIMENTAL METHODS

The experiments to be described were made on Green Mountains, on Aroostook Farm, near Presque Isle. A John Watson 4-row traction sprayer was used for the spray applications. There were 2 nozzles per row and the pressure maintained was about 200 pounds per square inch. We were able to regulate somewhat the rate of spray application by the use of nozzle disks with different hole diameters. We used a vine-protector device which pushes aside the potato foliage in front of the wheels, thus reducing mechanical injury. In making Bordeaux mixture the two equally diluted materials were poured together into the sprayer and 6¼ pounds of hydrated lime were used with each 5 pounds of copper sulphate (blue vitriol).

In 1926 and 1927 a Niagara gasoline-power potato duster was used for the dust applications. In 1928 the newer type of Niagara wheel-traction duster was used.

Unless designated otherwise, the statements as to copper content of fungicides are based upon the claims of the manufacturers. The use of trade names is for the convenience of potato growers. It should be remembered that materials used in these experiments may perform differently elsewhere with any variation in their composition or in growing conditions, equipment, etc.

Pressure and nozzles used in spraying

Some of the phases of methods have been dealt with in certain recent accounts. In New Jersey in 1928, a comparison of different pressures (150, 250, and 350 pounds per square inch) in applying Bordeaux mixture gave no significant differences in flea-beetle or leafhopper injury or in yield, though all gave improvement as against the checks (calcium arsenate alone). (*32.*)

Butler states that under the same pressure a smaller opening will give a finer and more penetrating spray, using less spray material to get the same effect. (*4*, p. 3.) The decrease in use of material, it also appears, would not be proportional to the decrease in the diameter or area of the nozzle opening. In New York in 1926, three nozzles per row were ineffective on plants over 18 inches high unless the boom was tilted back (*25*, p. 5) while in 1927 in one experimental field three nozzles allowed less foliage injury, from insects and disease, than two nozzles but gave no greater yield while in another field the yield also was greater with three nozzles (*24*). Aroostook vines also make three nozzles impractical. (*15*, p. 219.)

Mixing of Bordeaux

In making Bordeaux, according to Butler all methods of mixing are satisfactory except those in which the concentrates are combined directly; temperature and rate of settling are of no effect; and good hydrated lime is suitable. (*6.*) In Missouri, tests in three years, 1925-27, showed that in the control of hopperburn the method of mixing Bordeaux is of minor importance. (*55.*) While in some regions the stone lime is more highly recommended, generally the more convenient hydrated lime is considered to be as desirable.

Time of dusting

In Bermuda the time advised for dusting is when the plants are damp and when there is little or no wind. (*8.*) A representative of a dust-selling company advises recently that in copper-lime dust "some carbonation of lime results on the plants, unless moisture is present at the exact time of application of the dust", though enough remains unchanged (according to his statement), and that "some of the otherwise best growers lose a lot of money by making their particular applications under windy and dry conditions." (*12.*)

The only experimental evidence on this problem of leaf wetness and dusting, additional to that reported by us previously (*15*, p. 279.), was secured in New York in 1920-22. There, with equal amounts of copper, dust was less effective against late blight,

early blight, flea beetles, leafhoppers, and tipburn, when applied to dry foliage than when applied to wet foliage. (*2*, p. 63.)

In New Hampshire where hand dusting of small fields has been attempted, wet foliage requires the operator to wear rubber boots to protect himself against chemical burning (*5*, p. 16), a type of injury reported by us previously (*15*, p. 279).

EXPERIMENTS IN 1926

First series

One test was laid out on Caribou and Washburn loam (mostly the former) with plots 536 to 715 feet long, and with 3 sprayed plots, of 8 rows each, alternating with 3 unsprayed control plots, of 6 rows each. Seven applications of 5-5-50 Bordeaux mixture totaled 420 gallons per acre and gave nearly perfect control of early blight and late blight. Insect control was not important.

On August 25, one plant infected with late blight was noted in each of two unsprayed plots. A trace of early blight was also noted on the unsprayed controls. A period of rather warm and humid weather followed. (See Fig. 17.) On September 14 a general infection was present in the two unsprayed plots and a trace of late-blight infection had occurred in the sprayed plots. The two infected plants noted on August 25 appeared to be the sources of spread. The prevalence of late blight decreased with increase of distance from these two early sources of inoculum.

A killing frost occurred on September 30. At that time the difference between plots was very striking, those sprayed being still green and growing while the adjacent check plots were largely dead and defoliated. It is evident that the time of the killing frost determined to a large extent the increase in yield due to spray applications. If a frost had occurred two weeks previously, as is often the case in Aroostook, it is doubtful whether spraying would have given an increase in the yield. On the other hand with a later frost the plants kept green by spray application would no doubt have given a higher yield than was obtained.

Although 7 applications of spray gave practically perfect control against late blight, one application made through error on a check plot on August 25 gave practically as good control of foliage infection and gave the highest yield per acre of the 6 plots of this test.

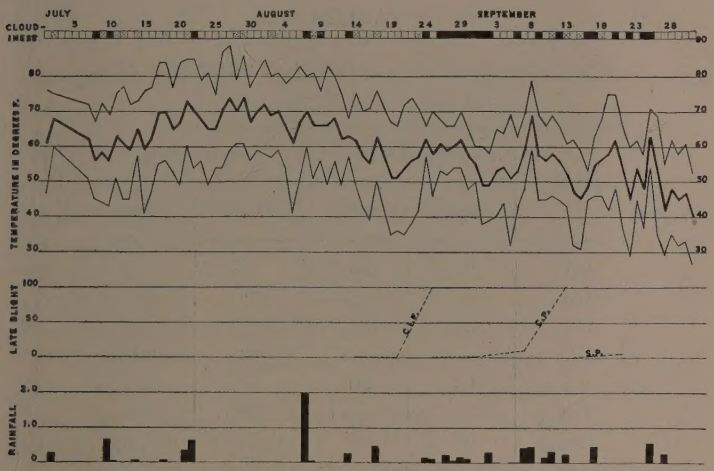

FIG. 17. Season of 1926 on Aroostook Farm. At top, clear, partly cloudy, and cloudy days are designated respectively by blank, dotted, and black squares. Below, to correspond, are daily maximum, mean, and minimum temperatures. Late blight is indicated as the percentage of plants infected in the center of the infection area first detected (C. I. F.), in control plots (C. P.), and in sprayed plots (S. P.) At bottom are shown the inches of rainfall on different dates.

The crop of the 4 middle rows of each plot was weighed and the yield per acre calculated. Table 1 gives the yield data. It is noted that the sprayed plots gave an increase in all cases over the adjacent checks. Calculations made according to Student's method (*30*; *31*) give odds (probability) of 17.9 to 1 that this gain is significant and due to the application of Bordeaux spray. These odds are too small to prove that the sprayed plots showed a significant increase. Therefore it is interesting to compare the effects of spraying in another test, which will be described below.

First, however, it should be noted that rot developed in about 1 per cent of the unsprayed stock in the field by digging time and in about 7 per cent additional in bin storage by May, 1927. Rot developed in only 2 per cent in barrel storage. In Maine in 1926, shipping-point inspectors at Presque Isle estimated that "an average of 8 to 10 per cent of the Maine potatoes in storage on December 1 were lost on account of rot". (*22*.)

TABLE 1

Yield rates per acre in sprayed vs. unsprayed plots on Aroostook Farm, 1926

Plot No.[1]	Sprayed Plots		Control Plots	
	Barrels	Bushels	Barrels	Bushels
S–1	122	335	—	—
O–1	—	—	110	304
S–2	128	352	—	—
O–2	—	—	123	338
S–3	125	343	—	—
O–3	—	—	130	356
Average	125	343	121[2], 117[3]	333[2], 321[3]

[1]Given in order here as the plots were arranged across the field from south to north. Spraying is indicated by S, and controls by O.
[2]Including plot O-3 which was sprayed through mistake on August 25.
[3]Not including plot O-3.

Second series

In another part of the same 20-acre field, a comparison was made between the progeny of unsprayed and the progeny of sprayed parts of the same Green Mountain field grown in 1925. Here the two kinds of stock were compared both with spray and with no spray applied in 1926. Hence there was a chance to make a second test of the effects of spraying, which was done as on the test area described above.

The plots were two rows wide and about 500 feet long, and were arranged so that sprayed and unsprayed plots from the same seed source adjoined each other. The unsprayed plots were practically dead on September 20 while the sprayed ones were still green when killed by frost on September 30. The increase in yield from spraying was not consistent and was not significant according to Bessel's or Student's methods of analyzing data. Seed source had no effect on the results of spraying. Other effects of seed source will be described later.

Experiments in 1927

First series

In 1927 the spray experiment included 10 replications comparing standard homemade 5-5-50 Bordeaux mixture with unsprayed control plots and with plots sprayed with colloidal copper.[5] The Bordeaux plot in each case was between a colloidal copper plot and an unsprayed control plot. Colloidal copper has been advocated as a cheaper fungicide at least with respect to the amount of copper needed. Preliminary trials in 1926 on Aroostook Farm indicated that this preparation had value.

In 1927, eight applications of Bordeaux mixture were made using about 535 gallons an acre in all. In this spray comparison, about 590 gallons of the colloidal-copper "solution" (sol) was used per acre.

During this season, insect control again was not important. On July 27 late blight was first noticed on a potato stalk in a cloth-covered cage at the laboratory plots. This cage had a solid wooden bottom and the soil in which the plants were grown had been sterilized previous to planting. This would indicate that the cause of infection had been carried in by the atmosphere.[6] Two days later two diseased leaflets were observed in our seed plot on Aroostook Farm and on August 2 a diseased leaflet was discovered on an unsprayed plant in the spray-test plots. This last blighted leaflet had furnished inoculum so that by the next day infected plants were noted for a radius of 10 feet. One diseased leaflet was found on the same day about 100 feet away in the same plot. This points out how rapidly even a very small source of infection can spread the disease under certain conditions. This spread apparently occurred within 24 to 36 hours. At that time inoculum must have been disseminating freely in

[5]The colloidal copper was prepared by Dr. Wilcoxon of the Boyce Thompson Institute, Yonkers, New York, and applied as recommended by him (4 pints of paste to 75 gallons of water). The preparation is in the nature of a liquid paste easily "dissolved" (dispersed) in water. It is of a yellowish color and not easily detected on potato foliage. At this rate about ⅓ as much copper was applied per acre as with the Bordeaux mixture.

[6]When late-blight spots at their first appearance are uniform in size and in distribution over an entire field, several to a plant, as seen sometimes in our plots, it seems evident that the cause can be air-borne from some distance.

Aroostook and this probably was a critical period for the late-blight epidemic which resulted several weeks later. It is very doubtful whether most potato growers or observers would detect the disease at the very earliest stages. They do not see the disease until most of the plants have become infected and growers often begin the spray operations some time later when it is most convenient. This results in failure provided the natural elements are not in their favor. It should be repeated here that one spray application made on Aroostook Farm in 1926, at the time when the first trace of blight was noted, resulted in good disease control and also in the highest yield of the six plots included in the experiment.

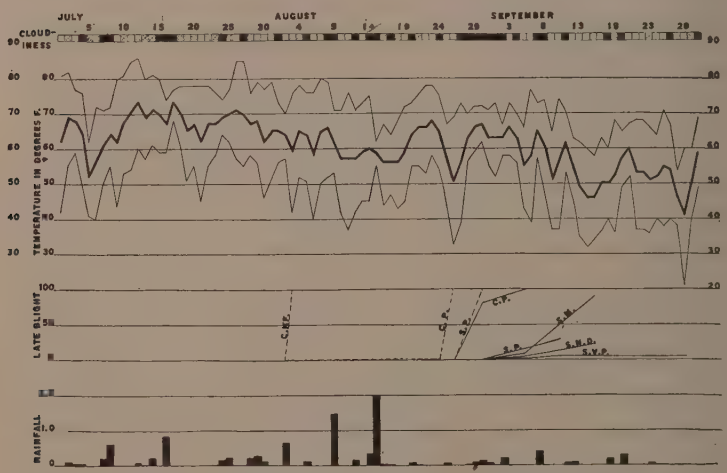

FIG. 18. Season of 1927 on Aroostook Farm. For explanation see legend for Fig. 17. Also, late blight is indicated by solid lines as percentage of foliage destroyed in control plots (C. P.) and in various sprayed plots (S. P., S. M., etc.).

From August 3 to August 24 (1927) no great disease increase could be seen. Spread had been very gradual in the unsprayed plots. An occasional diseased leaflet could be found in the more remote sections away from the earlier sources of inoculum. On August 13 and 14, heavy rains fell. Fig. 18 indicates a drop in the temperature which might account for a slowing in the rate of increase of late blight at that time. (See *15*, p. 255.) Much

dissemination and inoculation probably resulted but was not evidenced by mere field observations. The temperature then rose from August 19 to August 24, and from August 27 to September 2 there was only cloudy weather. No great change in the amount of disease was seen on August 24 but on August 26 it was noted that spread was exceedingly rapid, infection had become general in all unsprayed plots, and an occasional diseased leaflet was discovered in the well sprayed plots. It seems that the plants in many commercial fields were dead at that date. On August 30 our unsprayed control plots were about 81 per cent dead and by September 5 had practically dried up. At that time the adjacent plots sprayed with Bordeaux mixture had a general but light infection which could hardly be noticed without careful observation. By September 10 it was estimated that about 32 per cent of the foliage in these sprayed plots was dead. This might appear to be a high amount of infection but it should be considered that they were subjected to the most severe test inasmuch as each sprayed plot was only 4 rows wide and was bordered on both sides by diseased plots which furnished a continual supply of viable spores. On glass slides exposed in the field at that time and examined with the microscope, late-blight spores were seen in great abundance.

TABLE 2

Yields per acre in spray plots of 1927

	Bordeaux mixture		Unsprayed		Colloidal copper	
	Bus.	Bbls.	Bus.	Bbls.	Bus.	Bbls.
Plot Yields	360	131	327	119	335	122
	348	127	312	113	343	125
	366	133	324	118	353	128
	357	130	309	112	329	119
	357	130	313	114	322	117
	366	133				
	365	133	325	118	339	123
	362	132	312	113	344	125
	375	136	345	125	364	132
	390	142	319	116	350	127
	378	137	338	123	356	129
	393	143				
Mean	368	134	322	117	344	125
Percentage gain	13.7	13.7	—	—	6.5	6.5

The vine-protector plots (to be described later) were adjacent to the spray plots on the south but were not interspersed with unsprayed sources of infection. In the former, individual plant examination (Sept. 10) showed only from 10 to 12 per cent of the foliage dead in the east series of plots and practical freedom from blight in the west series. These plots were given the same treatments as the sprayed plots mentioned in the spray experiment. They remained green and upright until September 28 when killed by frost, with very little injury from blight.

The importance that diseased plants have on the dissemination of late blight is thus emphasized. During the season it was possible to trace the spread of infection from the nearby diseased sources. The Bordeaux plots first developed late blight where the rows bordered onto the unsprayed controls which had become diseased early in the season. As mentioned above, within 36 hours of ideal climatic conditions a single diseased leaflet could result in infection for a radius of 10 feet. The vine-protector plots, all sprayed, were for all practical purposes free from disease in those sections most remote from the unsprayed checks. A series of sprayed fertilizer plots, separated from the disease source by only 50 feet, also remained disease-free until killed by frost on September 28.

The plots were 4 rows wide and were divided across the middle into an east and a west series so as to double the number of replications. Each final plot was 200 feet in length. Only the 2 middle rows, making 400 feet of row, were used for obtaining the yield. The 2 border rows were left as buffers because the spray drifted somewhat, even in quiet weather. Table 2 gives the yield rates of the plots with averages for the series.

The yields of the Bordeaux-mixture plots were paired for statistical comparison with their adjacent unsprayed control plots. In all 10 comparisons the Bordeaux-mixture plots yielded more than the corresponding ones that were not sprayed. The average increase got with Bordeaux mixture over nonspraying was 17 barrels or 46 bushels per acre (about 14 per cent). According to Student's method the results give great odds (more than 9999 to 1) that the increase is significant and not due to uncontrolled factors such as soil.

Comparing the Bordeaux plots with the adjacent plots sprayed with colloidal copper, the latter yielded less in all of the

10 comparisons. The average increase in yield of the Bordeaux plots over the colloidal-copper plots was 22.3 bushels or 8 barrels per acre (6.49 per cent). Here also the odds are highly significant (over 9999 to 1).

It seemed evident from field observations that the yield would be less for the colloidal-copper spray at the strength used here. Although colloidal copper controlled late blight to a large extent it did not withstand the more severe epidemic of late August. The test was severe because each plot was bordered on one side by an unsprayed control plot from which could spread an amount of late-blight inoculum enormously in excess of what normally would be present with the whole field sprayed. The colloidal copper might have given better results in a field without these unsprayed plots. Even Bordeaux mixture did not give its normal control in the same experiment, since on some of the same stock of potatoes which were only a short distance away and which were all sprayed, the same Bordeaux applications gave excellent control of late blight.

The plots sprayed with colloidal copper outyielded the adjacent nonsprayed plots respectively in all 10 replications. The colloidal copper gave an average increase of about 8 barrels or 21.1 bushels per acre (6.54 per cent) over nonspraying, with high odds that indicate a difference in yield really due to the application of colloidal-copper spray.

Less than one per cent of tuber rot was noted in the unsprayed plots when harvested. In both barrels and bins, after winter storage, we found about 1 to 2 per cent more rot following spraying than following nonspraying, the latter giving 1 to 6 per cent.

Second series

In a third field, Niagara 20-80 copper-lime dust and Niagara "Copodust" were compared with 5-5-50 Bordeaux spray. Six applications were used in this test, at each of which the spray was applied at the rate of about 70 gallons per acre and the dusts at the rate of about 35 pounds per acre or again with 50 per cent more copper in the dust. Both of the dusts and the spray gave good disease control in these plots. During the exceedingly severe blight weeks beginning with August 26, some infection occurred.

It was not possible to detect a difference in disease control for the three fungicides. On September 15 about 75 to 80 per cent of the plants were green in the plots where the fungicides had been used. The control plots had been dead for about 2 weeks.

On critical examination it was found that the dusts had caused some foliage injury. Nearly all of the plants had very small rather inconspicuous spots. It is not known what constituent part of the dusts caused this injury, or whether it is a factor in production.

Sodium fluosilicate, where used in one field primarily for testing its effects on insects, gave nearly as good control of late blight as did the copper-lime dusts. However, when used as a dust, this material caused severe burning of the foliage where heavy dews collected.

EXPERIMENTS IN 1928

First series

In 1928 Bordeaux mixture (5-5-50) and untreated controls were compared with two commercial dusts and a colloidal-copper paste.[7] Niagara 25-75 dust is a mixture of finely ground dehydrated copper sulphate and hydrated lime. Lucas-Kiltone 9-per cent dust is a dried and pulverized Bordeaux mixture. These preparations represent two of the general types of copper dusts commonly used by farmers in Aroostook. The colloidal-copper paste is still in the experimental stage. It was included in these tests because it had previously shown promising fungicidal qualities and is relatively simple to use.

Eight applications of each of the various fungicides were made during the season. About 735 gallons of the Bordeaux mixture, containing about 18 pounds of copper, were applied per acre. About the same number of gallons of the colloidal-copper "solution" (sol) were used per acre, containing about 9 pounds of copper. That is, this material was used at half strength instead of at third strength as in 1927. Of each dust, about 235 pounds per acre was used, containing about 21 pounds of copper.

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[7]This colloidal-copper paste was supplied by Dr. Frank Wilcoxon through the courtesy of the Nichols Copper Company of Laurel Hill, New York. See footnote [5].

During the season of 1928, flea beetles (*Epitrix cucumeris*) and leafhoppers (*Empoasca mali*) were relatively few in number and caused very little foliage injury. Potato beetles were also few and required but one application of calcium-arsenate spray. The unimportance of insect control this season obliges us to credit the benefits of spraying and dusting here to the control of fungous diseases.

All of the full-strength fungicides used gave very good control of late blight. It was not possible to conclude that any one of them was definitely superior to the others. The plots where dusts had been used matured somewhat earlier than did the plots sprayed with homemade Bordeaux mixture. The colloidal-copper plots also withstood the late-blight epidemic very well. Although the foliage became slightly infected with late blight, the general appearance of the plots was slightly superior to that of the others. The leaves and tops were very large and remained erect, attracting the attention of many visitors. It seems that colloidal copper did not show the retardation of plant growth that accompanied the application of the other fungicides. Late blight destroyed the potato foliage in the control plots before early blight was severe. Early blight caused very little injury in the plots where fungicides were used. It seems that early blight was not controlled as well by the two dusts as by Bordeaux mixture and by colloidal-copper sprays.

The arrangement of the treatments with respect to each other in each series is indicated in Table 3. The treatment series involved 4-row strips 12 feet wide and 480 feet long. For yields each strip was divided crosswise into two equal parts. Because of border effect from both disease and fungicide, yields were taken only on the two middle rows. This gave 12 harvested areas each with an area of 1440 square feet (6 x 240) or about 1/30 acre. One of the 12 groups of harvested areas was discarded because of obvious differences in topography and soil. The average yields for the treatments (each based on 11 replicated plots) are given in Table 3. According to Student's method the treatments were all significantly superior to their respective adjacent untreated control plots, the odds being in all cases over 9999 to 1 in favor of the treatments. The colloidal-copper plots gave the highest yield, 403 bushels or 146 barrels per acre, which is somewhat significantly superior to the adjacent series dusted with Lucas-Kiltone dust, the odds being 114 to 1 according to Student's method.

TABLE 3

Average yields for different fungicidal treatments in 1928[1]

Treatment[2]	Average yield per acre	
	Bushels	Barrels
Bordeaux mixture (5-5-50)	397	144
Control (no fungicide)	347	126
Lucas-Kiltone dust (dried powdered Bordeaux)	392	143
Colloidal copper	403	146
Control (no fungicide)	329	120
Niagara dust (copper-lime mixture)	395	144

[1]The average yields are here based on 11 replicated plots, and are of total tubers rot-free at harvesting.
[2]The plots were all sprayed once with calcium arsenate for the control of Colorado potato beetles.

The probable errors of the average yields for the treatments were determined by Bessel's formula[3]. Here no fungicide was proved biometrically superior to the others. Colloidal copper gave slightly the best yield, but the difference is not regarded as significant. The plots receiving fungicidal treatments were all decidedly superior to the control plots, giving increases of 45 to 74 bushels or of 13 to 23 per cent, in total tubers rot-free at harvesting. Shrinkage in storage due to rot was less than one per cent in both sprayed and unsprayed stock in poorly ventilated bins.

Second series

In another series of plots a comparison was made between standard home-mixed Bordeaux mixture and a dried, powdered Bordeaux (Lucas-Kiltone Dry Bordo, 22% copper) used as a liquid spray. If such commercial material can give good disease control, it will be welcomed by many growers because of the ease

[3]The probable error of the mean is expressed by the formula $\pm.6745\frac{\text{S. D.}}{\sqrt{n}}$ in which S. D. refers to the Standard Deviation and n to the number of replications.

of preparation. The two sprays were made up so as to contain the same amounts of metallic copper. The field plots were arranged so as to permit adjacent comparisons of the two kinds of Bordeaux spray with untreated controls. Seven 4-row replications, each 160 feet in length, were included in this test. During the summer it appeared that the standard Bordeaux mixture was only slightly, if at all, superior to the powdered Bordeaux in the control of late blight. The average yield for the Bordeaux mixture was 357 bushels compared to 354 bushels for the Dry Bordo. The difference is not biometrically significant. Both gave significant gains over the controls.

Following up the 1927 results with sodium fluosilicate, this material was mixed with hydrated lime (respectively 2 and 5 pounds in 50 gallons of water) and applied as a spray. No fungicidal value could be noted, although the strength was increased further until foliage burning resulted.

SEASONAL DIFFERENCES

After adding the results of 1926, 1927, and 1928 to those of the previous ten years (*15*, p. 244) we get for the 13 years an average yield of 117 barrels or 323 bushels for the nonsprayed plots and a gain of about 9 barrels, 26 bushels, or 8 per cent by using Bordeaux mixture. This is on Green Mountains grown in Caribou loam on or near Aroostook Farm. In other words, under the conditions of these tests, a grower could reasonably expect the cost of spraying to be balanced if it were equal to the income from 9 additional barrels of field-run crop. The effect of spraying varied considerably with the season, running from a 14 per cent loss to a 28 per cent gain. The average of the seasonal percentage gains is a 10-per cent gain. This is less important than the percentage given above and differs from it because a given increase of crop represents a greater percentage in a low-yielding season than in a high-yielding season.

In 1927 we found the first evidence of blight about three weeks earlier by the calendar than in 1926. The weather graph (Fig. 18) shows that in 1927 we had cloudy weather combined with sufficient and well distributed rainfall and with rather warm weather. These factors evidently favored an early development of late

blight. It is shown on the graph for 1926 (Fig. 17) that the days in July were to a great extent clear and the rainfall infrequent, which probably postponed the initiation and spread of late blight.

In our last bulletin we showed that in each of three regions where the matter has been studied (Maine, New Jersey, and Vermont) there is a combination, varying with the region, of mean temperature, rainfall, and part of the season which usually is correlated with severity of late blight (*15*, p. 250-256). Other influential factors, some more or less dependent upon temperature and rainfall, were suggested. However, no practical use can be made of such general conclusions, even if they were more dependable than they are, because of the present inability of meteorologists to forecast the weather with more than about 75-per cent accuracy for one or two days, or with any accuracy for more than several days.

The great seasonal differences in insects, diseases, yields, and benefits of spraying, have led to two different points of view. One is that there is need for official advice, commonly called potato spray service, as to postponing the first applications until late blight has appeared, or as to the need of special care in getting applications made at certain times. The other viewpoint is that a potato grower should always apply fungicides so that he will be sure of protection in the worst season. This requires useless expenses in the seasons of lighter disease. With this view it is necessary to consider the cost of the most complete schedule needed against the average profits over a period of years. This will be done in a later section of this bulletin.

The real solution of the problem of seasonal differences is either to develop a potato variety that is immune to the various insects and diseases requiring the application of copper materials, or to develop a system of forecasting the weather for several months in advance. Neither solution is in sight at present.

MATERIALS

COMPARISON IN AROOSTOOK COUNTY

Five years' results are available for the comparison of spraying and dusting with standard Bordeaux mixture and copper-lime dust respectively. After adding the results of 1928 to those of

the four years 1922-25 (*15*, p. 244), we get an average yield of 121 barrels or 332 bushels for the untreated control plots, a gain of 6 barrels or 16 bushels for the sprayed plots, and a gain of 7 barrels or 18 bushels for the dusted plots. It should be emphasized here that in our plots dusting had to be done during quiet periods, to prevent drifting of the dust onto control and sprayed plots, and that such quiet periods were rare except early on clear mornings when the foliage was covered with dew. These conditions may possibly be more favorable for the effectiveness of dust than dry, windy conditions which prevail during much of the time in Aroostook County and during dusting as carried on by many growers.

It is of interest that during 1928 there was a severe late-blight attack and yet several kinds of dust and spray materials, as used, gave as good results as the standard Bordeaux mixture. (See the previous section on experiments in 1928). In other seasons or parts of Maine with certain insects and other diseases more abundant, or in seasons where no copper is needed and even proves detrimental, as in 1923, the relative value of the different materials may be different. A comparison of materials as to costs will be made in a later section of this bulletin.

Comparisons in Other Regions

Reports of tests made in other regions are of some value regarding both the effect of standard materials and the comparative effects, of standard and newer materials, to be expected in Maine.

Injury

In our last bulletin we gave instances of Bordeaux spraying not increasing the yield in various regions. (*15*, p. 259-262.) Since then similar instances have been reported. In New Hampshire in 1922 with late blight absent, the amount of Bordeaux mixture applied had no stimulatory effect on the yield of the plants. (*45*, p. 24.) Again, there in 1924 with diseases absent there was no significant effect upon yield from either dusting or spraying. (*47*, p. 17.)

In Connecticut in 1923, the vines of Green Mountains and Irish Cobblers lived longer with 8 applications of Bordeaux mixture than in the untreated check plots, and yet yielded less. The explanation is given that "soil inequalities, not apparent to the eye, may have nullified the effects of spraying." (*3*, p. 35.) Such an explanation could as well have been, but was not,

used to explain the apparent yield increases due to spraying during the preceding year. Probably it was not justified in either year, inasmuch as in 1923 the plots sprayed only 4 times yielded more, or as much as, the corresponding plots sprayed 8 times and the corresponding untreated check plots. We would prefer the explanation that in 1923 the 4 applications gave a more gainful relationship between inhibition of enemies and copper injury than 8 applications. This same year in Maine in 6 instances a sprayed plot yielded less than the adjoining plots which were respectively dusted and untreated. (*15*, p. 237.) Such results can not be explained on the basis of rhythmic variation of soil as well as on the basis of the injurious effects of spraying being greater at times than its beneficial effects.

In New York in 1920-22, the percentage of copper in copper-lime dust could differ from 6 to 10 per cent with no difference in effect upon late blight, flea beetles, and yields. Over 10 per cent, if freshly mixed, caused leaf burning in proportion to the percentage. (*2*, p. 63.)

In New York in the three years 1920-22, "there was strong indication, throughout the series of experiments, that heavy coatings of either dust or spray produced a dwarfing or a stunting effect on the plants. This effect was entirely independent of the occurrence of copper injury on the leaflets" (consisting of the spotting due to high percentages of copper in freshly mixed dusts). "There was repeated evidence also of plant injury, accompanied by reduction in yield, due to the passing of horses and machines through the plots", but when the check plots were subjected to the same mechanical injury as the others with the latter still showing a stunting effect, it was concluded that the copper coating probably had a direct injurious effect. This sometimes resulted in sprayed and dusted vines, especially the former, living longer with less injury from insects or diseases and yet yielding the same or even less, than the checks. This occurred with several varieties, including the Green Mountains. (*2*, p. 33, 36, 39, 40, 41, 44, 57, 59-60, 63, and 64.) Later results in the same State by a different worker showed that "apparently severe injury to the potato plant by the premature loss of foliage did not affect in like degree the yield of tubers" (*25*, p. 1) due, in our opinion, to copper making the foliage less efficient during the most of the season. Stated in another way, the yield in sprayed plots sometimes is less than the longevity of the leaves would indicate. (*26*.)

In New Jersey in 1924 with early blight and hopperburn present, in Irish Cobblers either the 100-bushel variation between check plots prevented a true average or else both dusting and spraying decreased the yield, spraying doing so more than dusting. (*34*, p. 465.) In 1925 in one test out of a total of 4, the early frost-killing of the vines prevented yield increases by spraying. (*37*.) In 1926 in one comparison wherein early blight was causing injury, 5-5-50 Bordeaux mixture increased the yield when applied in the usual way, but when applied in opposite directions each time (double spraying at each application) a slight increase in early-blight control did not prevent a decrease in yield below the check-plot yield. (*33*.)

In eastern Virginia "no increase in yield due to spraying with Bordeaux or dusting with copper lime dusts occurred even when harvesting was delayed until all vines were dead." Early blight does not appear until late and

late blight does not attack the crop. "The Colorado potato beetle . . . and aphids are the only potato insects of economic importance which can be controlled by dusting or spraying." (*62.*) In Wisconsin during four years, 1922-1925, in one instance a Bordeaux-sprayed plot yielded less than an untreated check plot. (*11,* Table IV and p. 15.) In Kansas in the absence of foliage diseases, liquid Bordeaux gave yield decreases in two years, nonsignificant increases in three years, and a barely significant increase in one year. About the same lack of value was secured in four years of experimental dusting. (*61.*)

In Quebec in 1926, with no late blight and with much dry weather during July and the first half of August, decreases in yield occurred in 3 of the 4 plots with applications of Bordeaux spraying beginning July 20 or later. (*19,* p. 54.) In New Brunswick in 1926, 20-80 copper-lime dust controlled late blight well in Green Mountains without however giving significant increases in total yield. (*19,* p. 51-53.)

The preceding review shows that spray injury is not peculiar to Maine. The results in which Bordeaux spraying has shown an increase in yield have been sufficiently advertised and will be referred to here only in comparison with newer kinds of materials.

Control of late blight on foliage

With regard to control of late blight on the foliage, Bordeaux spray was superior to copper-lime dust in New Brunswick in 1927 (*20,* p. 215-218), and in Prince Edward Island in 1927 (*20,* p. 218) and in general (*54,* p. 296). The two were equal in New Hampshire (*50*), in New York in 1920-22 (*2,* p. 63), in Florida in 1926-27 with the disease "exceptionally severe" (*14,* p. 71-72R), in New Brunswick in 1925 in one field with the disease severe (*1,* p. 34-35), in New Brunswick in 1926 (*19,* p. 51-53), and in Quebec in 1927 (*39,* p. 35-36). The dust was superior in New Brunswick in 1925 in another field likewise with the disease severe (*18,* p. 47-48). A dried-Bordeaux dust proved almost as effective as Bordeaux spray and copper-lime dust on Green Mountains in New York in 1920. (*2,* p 29.) Copper-carbonate dust was inferior to Bordeaux spray and copper-lime dust in New Brunswick in 1925 (*18,* p. 47-48), copper-carbonate spray and dust failed to control the disease in Green Mountains in New Brunswick in 1926 though copper-lime dust and Bordeaux mixture controlled it well (*19,* p. 51-53), and there in 1927 copper-carbonate dust was ineffective, like copper-lime dust, and copper-carbonate spray was effective, like Bordeaux mixture (*20,* p. 215-216). Burgundy mixture (sal-soda Bordeaux) was equal to Bordeaux mixture in New Brunswick in 1927 on Green Mountains. (*20,* p. 215-218.)

Control of late-blight rot

With regard to the prevention of late-blight rot, Bordeaux mixture was superior to copper-lime dust in New Brunswick in 1927 (*20,* p. 215-217) and in Prince Edward Island in 1927 in Green Mountains and Irish Cobblers (*20,* p. 218). The two were equal in Quebec in 1927 (*39,* p. 35-36). The dust was superior to the spray in New York in 1927 (*24,* p. 8), in New

Brunswick in 1925 (*18*, p. 47-48), and in New Brunswick in 1928 each applied twice to the defoliated stems and the soil (*20*, p. 214). "Pota" dust, made by a secret commercial process (*20*, p. 215), permitted more rot to develop than copper-lime dust or Bordeaux spray in New Brunswick in 1927 (*20*, p. 217) or than Bordeaux mixture in Prince Edward Island in 1927 (*20*, p. 203). A copper-carbonate dust was inferior to Bordeaux mixture and copper-lime dust in New Brunswick in 1925 (*18*, p. 47-48) and was respectively inferior and superior to them there in 1927 (*20*, p. 217). Copper-carbonate spray was about equal to Bordeaux spray in New Brunswick in 1927 (*20*, p. 217). Burgundy spray was superior to Bordeaux spray in New Brunswick in 1927 (*20*, p. 217).

Control of early blight

With regard to control of early blight on the foliage, Bordeaux spray was somewhat superior to copper-lime dust in New Hampshire in 1923-26 in experiments (*5*, p. 16) and there in general (*50*), and in Prince Edward Island (*54*, p. 296). The two were about equal in New York in 1920-22 (*2*, p. 63) and in New Brunswick in 1927 (*20*, p. 217). The dust was superior in New Brunswick in 1925 (*18*, p. 47-48). Copper-carbonate dust was inferior to Bordeaux spray and copper-lime dust in New Brunswick in 1925 (*18*, p. 47-48) and to the latter there in 1927 (*20*, p. 215-218) while copper-carbonate spray was superior to Bordeaux spray there in 1927 (*20*, p. 215-218). Burgundy mixture was superior to Bordeaux mixture in New Brunswick in 1927. (*20*, p. 215-218.)

Control of flea beetles

With regard to control of flea beetles on the foliage, Bordeaux spray was superior to copper-lime dust in New Hampshire (*50*), in New York in 1920-22 (*2*, p. 63), in 1926 (*25*, p. 1, 10), and in 1927 in the second brood (*24*, p. 8), and in New Jersey in 1925 (*37*). The two were equal in the first brood in New York in 1927 (*24*, p. 8). A dried-Bordeaux dust was almost as effective as Bordeaux spray and copper-lime dust in New York in 1920 (*2*, p. 29).

Control of leafhoppers

With regard to control of leafhoppers or hopperburn or both, Bordeaux spray was superior to commercial copper-lime dust in New Hampshire (*50*), in New Jersey in 1925 (*37*) and in 1926 (*33*), in New York in 1920-22 (*2*, p. 63), in 1926 (*25*, p. 1, 10), in 1927 (*24*, p. 8), and in general (*7*), in Wisconsin (*11*, p. 13), in Ohio in 1925 in one test (*53*, p. 36; *57*; *60*) and in 1927 (*53*, p. 36; 58). The two were about equal in Michigan in 1926 (*43*). The dust was superior to the spray in Ohio in 1925 in one test (*53*, p. 36; *57*; *60*) and in 1926 (*53*, p. 36). Copper-lime dust fresh-mixed at home was superior to Bordeaux spray in Ohio in 1925 and 1926, was inferior to the spray there in 1927, and was superior to the commercial copper-lime dust there in all three years. (*53*, p. 36; *57*; *58*; *60*.) A commercial Bordeaux was about equal to homemade Bordeaux mixture in Ohio in 1927 (*58*) but inferior in

New Jersey in 1926 (*33*). Copper-hydrate dust was inferior to Bordeaux in New Jersey in 1925. (*37.*) Copper-stearate dust was inferior to copper-lime dust in Ohio in 1926. (*52,* p. 39.)

Prevention of tipburn

With regard to the prevention of tipburn, Bordeaux spray was markedly superior to copper-lime dust in New Hampshire in 1923-26 (*5,* p. 16) and in 1927 (*49,* p. 22) in experiments, and there in general (*50*), and in New York in 1920-22 (*2,* p. 63). The dust was superior to the spray in New Hampshire in 1926 when containing considerably more metallic copper (*48,* p. 14). A dried-Bordeaux dust was almost as effective as Bordeaux spray and copper-lime dust in New York in 1920 (*2,* p. 29).

Increase of yield

With regard to increasing the yield over that of the check plots, Bordeaux spray was somewhat superior to copper-lime dust in New Hampshire in 1923-26 (*5*), in New York in 1920-22 (7.2 bushels an acre average) (*2,* p. 63) and in 1927 (*24,* p. 8), in New Jersey in 1925 (*37*) and in 1926 (*33*), in Michigan in 1926 (10 bushels more) (*43*), in Ohio in 1925 in one test (*53,* p. 36; *57*; *60*) and in 1927 (*53,* p. 36; *59*), in Wisconsin in 1922-25 (*11,* p. 15), and in New Brunswick in 1925 (*1,* p. 34-35). The two were about equal in New Brunswick in 1927 (*20,* p. 216) and in Prince Edward Island in 1927 (*20,* p. 218). The dust was superior to the spray in New Hampshire in 1926 with considerably more metallic copper present (*48,* p. 14), in Ohio in 1925 in one test (*53,* p. 36; *57*; *60*) and in 1926 (*53,* p. 36; *60*) with the difference proved significant by Student's method (*52,* p. 39), and in Quebec in 1923-27 (*39,* p. 35-36). The spray was more harmful in New Jersey in 1924 (*34,* p. 465). Fresh home-mixed copper-lime dust was superior to commercial copper-lime dust and to Bordeaux spray in Ohio in 1925 and 1926 (*52,* p. 39; *57*; *60*) and in 1927 (*58; 59*). A dried-Bordeaux dust was almost equal to copper-lime dust and Bordeaux spray in New York in 1920 (*2,* p. 29). A commercial-Bordeaux spray was inferior to homemade Bordeaux in New Jersey in 1926 (*33*). "Pota" dust was inferior to copper-lime dust and Bordeaux spray in New Brunswick in 1927 (*20,* p. 215-218), was about equal in Quebec in 1927 (*20,* p. 223), and was superior in both Green Mountains and Irish Cobblers in Prince Edward Island in 1927 (*20,* p. 203). Copper-carbonate dust was inferior to Bordeaux spray and copper-lime dust in New Brunswick in 1925 (*18,* p. 47-48) and about equal to them there in 1927 (*20,* p. 216). Both copper-carbonate spray and Burgundy mixture (sal-soda Bordeaux) were superior to Bordeaux mixture (lime-Bordeaux) in New Brunswick in 1927 (*20,* p. 215-218). Copper-hydrate dust was inferior to Bordeaux in New Jersey in 1925 and somewhat inferior to copper-lime dust (*37*). Copper-stearate dust was inferior to copper-lime dust in Ohio in 1926 (*52,* p. 39; *60*).

PLOT TECHNIQUE

Many of the preceding comparisons would have more value if the plot technique were different. Each kind of treatment should be tested on enough plots to determine how much variation exists due to unknown or uncontrolled causes. How many plots that is, depends somewhat upon the location of the test and must be determined with the aid of biometrical formulae. Further, the total area and arrangement of untreated plots are important.

As shown in our own tests of 1927, frequent interspersing of check plots among treated plots may favor the development of a disease and increase the difficulty of controlling it, thus making the benefits of spraying or dusting less than they would be in a field with all parts treated alike with the fungicide.

On the other hand, it seems to be ignored that probably a small untreated plot in a sprayed or dusted field would be more severely injured by flea beetles and leafhoppers, which are generally considered to be controlled by copper fungicides only through being repelled, than a number of untreated plots or the whole field untreated would be. The result of this would be greater loss per acre in the small plot from omitting spraying than would actually occur from omitting it in the whole field. The fact determined should be the loss per acre in whole fields not sprayed, rather than the aggravated loss in an unsprayed plot due to insects repelled from the remainder of the field.

CONCLUSIONS AS TO MATERIALS

In different regions tests of copper fungicides do not always show benefit sufficient to balance a generally depressing effect. Such injury is greater with sprays than with dusts, corresponding to a greater accumulation of copper on the leaves with the sprays. In many tests the conclusions as to comparative benefits are less reliable, even for the particular place and season, than they would be with a better plot technique. Altogether, the available recent reports show chiefly that the superiority of one kind of material over another depends too much upon place, season, disease, and insect infestation, to permit much reliable generalization. The most that can be said seems to be that Bordeaux mixture tends to surpass copper-lime dust in the control of flea beetles and leaf-

hoppers and in the prevention of tipburn. Also, various substitutes for these two kinds of materials have not proved effective enough to be recommended.

In view of our observations showing flea beetles and leafhoppers to be more abundant in other parts of Maine than in Aroostook County, copper-lime dust can not be expected to compare as favorably with Bordeaux mixture outside of Aroostook County as it does within.

VINE PROTECTOR

A vine protector was tested again in 1926 (see *15*, p. 265-268) in the same 20-acre field with the spray test. The schedule and results of spraying were the same as for the spray test. The field was planted on June 4 with Green Mountain seed pieces averaging 1½ ounces. Each plot consisted of 4 rows 3 feet apart. The sprayer and vine protector were used in such a way as to cause a difference between two series of plots with respect to foliage injury. The average increase in yield for the vine-protector plots was about 8 bushels or 3 barrels per acre over the 307 bushels or 111 barrels of the no-protector plots. An analysis of the results with Student's method (*30*; *31*) gave odds too small to prove a significant yield increase from the reduction in foliage injury.

Finally in 1927 the vine growth and the experimental technique permitted an adequate test of the possible value of the vine protector. The distance between rows was reduced to 34 inches, which is a common width in commercial practice. The vine protector was removed for the no-protector strips, in which the team was driven in the opposite direction in succeeding applications. It was a season when sprayed tops grew large. It was evident from general field observations that the vine protector eliminated much bruising of foliage, especially during the latter part of the season. One could readily detect the rows where the protector was not used while spraying, by the number of crushed vines and the beaten path made by the wheels down the rows. Field counts revealed that from 3 to 4 per cent of the plants were injured by the wheels having the protector and from 25 to 26 per cent in the rows where it was removed. The ten 200-foot 4-row protector plots averaged an increase of 19 bushels or 7 barrels an acre, which

was significant (odds of 555:1 by Student's method), over the similar set of no-protector plots which averaged 366 bushels or 133 barrels an acre.

This proved difference, together with the protector giving some gain in the two preceding years, indicates that there may be value in decreasing mechanical injury by spraying if the latter is to be done. The gain will vary greatly with conditions, but considering the low cost of securing and operating the protector, probably it would return a profit over a term of years if used correctly. It is best to start the use of the protector at the first application and to drive always in the same furrows and in the same directions, as otherwise the device will cause more damage than it will prevent.

EFFECT OF SPRAYING ON VIGOR OF NEXT YEAR'S PLANTS

Martin (*32*; *35*, p. 26 and 31) is of the opinion that tubers from sprayed plants are more vigorous than tubers from similar plants that have not been sprayed. In one experiment the progeny from unsprayed plants were on the average smaller than plants from stock that had been sprayed the previous season. Forty-five per cent of the progeny from the unsprayed plants had yellow leaves. Only 22 per cent of the progeny from plants that had been sprayed were chlorotic. He obtained a yield of 34.8 bushels per acre for the tubers from unsprayed plants and 48.7 bushels per acre for tubers from sprayed plants. These results prompted an experiment in 1926 to test the relative vigor of seed from sprayed and from nonsprayed stock in Aroostook County.

The seed for this experiment was in part from the sprayed and in part from the nonsprayed Green Mountain plots of the 1925 test, all planted from the same stock. The two seed lots were stored and handled in the same manner. Both lots of seed were cut by the same person into seed pieces averaging 1½ ounces. Each plot in 1926 consisted of two rows and the plots ranged from 492 to 555 feet in length. The plots as arranged in the field consisted of two series of comparisons. In one series the progeny from the sprayed and nonsprayed fields of 1925 were both sprayed in 1926. In the other series the same two lots of seed were com-

pared with no spray applied in 1926. In each series the compared plots were grown adjoining each other so as to facilitate the use of Student's method (*30, 31*) for making the biometrical calculations. There were 12 plots in all, making three receiving each kind of treatment.

The average yield was 330 bushels or 120 barrels an acre. In the six plots which were not sprayed during the season of 1926, the seed from the unsprayed plots of 1925 gave an increased yield over the seed from the sprayed plots in each of the three pairs, with odds of only 7.13 to 1 which are too small to be considered as significant. In the six plots which were sprayed in 1926, the seed from the nonsprayed plots gave a slightly increased yield over that of the seed from the sprayed plots in two pairs. In the third pair the sprayed seed stock gave an increase. The odds in this case are in favor of the sprayed plots, but are only 3.12 to 1, again proving to be not significant.

Therefore the results obtained in 1926 on Aroostook Farm failed to demonstrate that the vigor of seed potatoes is increased by spraying the parent plants with Bordeaux mixture. The increased vigor reported by Martin may, as he suggests, be due to more insect transmission of the virus diseases occurring in the fields which were sprayed. In northern Maine the insect population is no doubt much less than in New Jersey and less benefit might thus be derived from spray applications. This applies especially to flea beetles *(Epitrix cucumeris)* and leafhoppers *(Empoasca mali)*.

OMISSION OF EARLY APPLICATIONS

IN 1926 IN AROOSTOOK COUNTY

As occurred in 1923, copper fungicides may reduce the yield in the absence of diseases and insect pests (*15*, p. 236-237). Presumably such fungicides may be causing some yield reduction even when they give a net increase through checking diseases and insects. Furthermore, copper materials are undoubtedly costly. By 1926 these facts had made evident the desirability of fewer applications, if safe, so that in that season a plot was set aside to test the effect of postponing dusting until disease had appeared.

Dust was chosen for this experiment rather than spray because it was thought that dust could be applied more thoroughly and effectively through a mass of large vines than could spray.

The field for this work consisted of two 12-row plots, separated by 6 rows which were not treated. Adjoining the dusted plot on the north was the "spray-vigor" plot which received 7 applications of 5-5-50 Bordeaux liquid spray. This afforded a good comparison with the untreated check rows and the so-called "delayed-dusting" plots of this test. The north plot received "Niagara 20-80" dust and the south plot received "Sanders' dust", a product claimed to consist of finer particles and to be adapted for better distribution and adherence to the potato. The dust applications were made during the early morning while the foliage was moist and the air quiet. From 36 to 40 pounds an acre was used for each application.

The plots were observed each day to note the first appearance of late blight. On August 14 two plants were found to be slightly infected. These two plants were growing close together in a low portion of the "Sanders' dust" plots and were the first specimens of late blight seen by us in the summer of 1926. The diseased plants were staked and the progress of the spread of disease noted. Rain had fallen on August 13 and possibly spread the spores of the late-blight fungus about.

On the morning of August 18 the first dust was applied to the plots. On August 20 the field was carefully observed. At that time no evident spread from the earlier diseased plants had occurred. Meteorological records for Aroostook Farm indicate that the weather had been rather too dry for the rapid development of late blight. August 23 and 24 were very moist and rather warm. Dust was applied to the plots on August 25. At that time it was observed that late blight had spread considerably. Practically every plant in the dust plot had developed late blight for a distance of 25 to 30 feet in all directions from the previously mentioned first source of infection. The disease had become general in the center of the middle (check) plot and also had spread into the nearest Niagara dust plot. It is interesting to note that the amount of disease diminished as the distance from the two earlier infected plants increased. It also seems striking that the visible results of spread had developed to a conspicuous stage in a period of from 36 to 48 hours. A trace of late blight was noted in the dusted plots

in the more remote portions. No late blight was evident in the "spray-vigor" plots sprayed with 5-5-50 Bordeaux mixture.

Dust was applied on August 31, September 7 and September 14. Meanwhile late blight spread, so that on September 13 and again on September 21, observations revealed that practically every plant in the check plot was dead from late blight. The dust plots were still green except in the area about the early source of infection. About 30 per cent of the plants were infected in the dusted plots remote from the dead part of the field where infection occurred early. The plots sprayed with liquid Bordeaux were relatively free from late blight although a trace was noted.

Although 5 dust applications (about 200 lbs. per acre for the season) were made after the first evidence of disease, we did not prevent the spread of late blight from one small source of infection to the entire field. Although late blight was distributed throughout the dust plots, the amount of bin rot was very small. For the dust plots it was from 1 to 2 per cent compared with 10 per cent found in stock from untreated rows.

Seven spray applications with 5-5-50 Bordeaux mixture gave very good control of late blight in adjoining plots. Another plot about 300 feet away was sprayed only once (on August 25) and, as was stated in a previous section on the spraying and dusting tests of 1926, showed good control of late blight and gave higher yields than other plots which had been sprayed seven times during the season. Here the time of application appeared to be critical, serving to prevent entry of the disease from outside this plot rather than its spread from a source within the plot.

In 1928 in Aroostook County

On the basis of these results and other similar experiences, a series of plots consisting of seven replications were laid out in 1928, comparing a delayed-dust and delayed-spray program with our regular spray schedule. The regular spray plots received 8 applications beginning early and continuing throughout the season. The delayed program consisted of only 5 applications beginning at the time when disease was first detected in the field.

At the end of the growing season, the plots which received 5 applications of fungicides were superior in general foliage appearance to those which had received 8 applications, although late

blight was not controlled quite as well in the former. Late blight was not conspicuous in either series. The yields also indicated that the delayed schedule increased crop production more than the standard schedule. The average yield was 392 bushels (143 barrels) for the delayed program and 372 bushels (135 barrels) for the plots receiving the regular number of applications. The 20-bushel difference in favor of the delayed fungicidal schedule was not shown to be significant for these data, probably due to the variation between plots.

IN OTHER REGIONS

In Quebec in 1924, with late-blight injury not severe, and when spraying with 4-4-40 Bordeaux (4-4-50 in U. S. A. gals.), 6 applications beginning July 2 permitted less rot and more yield than 6 beginning August 1 or than 4 beginning August 1, but gave less rot and less yield than 4 beginning July 2. Four sprayings beginning July 2 gave more rot and more yield than 4 beginning August 1. (*17*, p. 29.) Apparently applications were most needed against blight rot after August 1, and yet the concentration of either 4 or 6 applications in this period decreased the yield as compared with the same number spread over the longer period.

Again, in Quebec in 1926, with no late blight and with much dry weather during July and the first half of August, there was increasing benefit from Bordeaux mixture as the applications were begun earlier, and decreases in yield occurred in 3 of the 4 plots with applications bginning July 20 or later. (*19*, p. 54.)

In Quebec in 1927, greater increases in yield resulted from 4 applications of spray than from 6. With 4 applications, the later the start, the greater the yield increase. With 6 applications, the later the start, the less the increase. (*20*, p. 223.) Apparently the spray was needed to the extent of 4 applications during the latter part of the season, with injury resulting from earlier applications or from additional applications during this period.

In New York in 1927, control of the first brood of flea beetles did not increase the yield. (*24*, p. 10.)

In Switzerland more than two applications were not profitable especially if these two were made just before damp, warm weather. (*44*, p. 509.)

CONCLUSION ON OMISSION OF EARLY APPLICATIONS

In conclusion, then, it is possible for a reduction in the number of applications to increase the yield. However, the results vary with the season, the source of disease (whether from an early-infection spot in the field or from other fields), the soil and location, the vine growth, the time of spread of the disease, the times of applications, and the nature of the fungicide. At present it is still necessary to make applications from the first to the last of the growing season of the vines if each and every possible attack of disease is to be prevented. It seems at present to be more profitable to experiment with materials that promise a reduction in the copper used or in the copper adhering to the leaves, without a reduction in the control of disease, than to take the risk of omitting certain applications.

COPPER CONTENT OF FOLIAGE

As a result of sampling and analyzing the foliage in 1923 (*15*, p. 273-278) it was concluded that "sprayed copper adheres better than dusted copper." In 1924 and 1925, samples were obtained in a similar manner.[9] The procedure of analysis was somewhat different, being as follows:

Dry sample to constant weight at 60° C. Ash the material, grind to a powder with agate mortar and pestle, dissolve the copper in boiling 1 to 4 nitric acid, filter, wash the residue with hot water until the filtrate measures about 100 cc., add 1 to 2 cc. of sulphuric acid and electrolyze, using a rotating spiral anode and a current of about 3 amperes.[10] After all of the copper is deposited, wash the deposit with water by siphoning, then rinse with alcohol, dry for a few minutes in an oven and weigh.

At first, to check this method, six samples of potato leaves (200 grams each) were obtained from plants grown in the greenhouse. Two samples, No. 1 and No. 2, were used as checks, one-tenth gram (0.1 gram) of Dosch 24-76 copper-lime dust, contain-

[9]Credit is given to Mr. C. Harry White, Associate Chemist, for the analysis of one-half of the 1924 samples.

[10]A special electrolytic apparatus for the determination of copper in insecticides and fungicides has been described by Holland and Gilligan. (*23*.)

ing 6.5 per cent of copper, was added to each of two samples, No. 3 and No. 4, and one and three tenths grams (1.3 grams) of Dosch 24-76 copper-lime dust were added to each of the remaining samples, No. 5 and No. 6. These six samples were dried to constant weight at 60° C. The weights varied from 14.5 grams to 17.0 grams. The samples were again dried at 100° C. The losses in weight, due to the additional drying, ranged from zero to one gram. The grams of copper in the six samples were respectively as follows:

Expected.. none...none...0.0065...0.0065...0.0845...0.0845
Found.....none...none...0.0062...0.0066...0.0850...0.0838[11]

As a result of tabulating and plotting on graphs the copper determinations, records of rainfall, and times of applications, it is apparent that in general there was two or three times as much copper per given dry weight of foliage when sprayed as when dusted, regardless of any effects of rain or number of applications. There was relatively more in 1925 than in 1924 and yet the superiority of spray over dust in yield was greater in 1924 than in 1925 and there was not much difference either year in disease control (*15*, p. 238-243).

Samples were taken again in 1928 when most materials were similar in effectiveness and in increasing the yield. Bordeaux mixture gave about twice as much copper per dry weight of leaves as colloidal copper, Niagara dust, or Lucas dust. Only half as much copper per acre was applied in the colloidal form as in the Bordeaux mixture, but more was applied in each dust than in the Bordeaux mixture.

The conclusion that sprayed copper adhered better than dusted copper in 1923 was not tested for the later seasons except for one pairing in 1928 which gave no consistent evidence as to the effect of a rather light rain. The accumulation of more copper with spraying than with dusting may be attributed to less waste of material during application, to better adherence during weathering, or to both. It is rather interesting that the greater accumulation did not make spraying more effective than dusting. This

[11]The residual solution of this sample contained a trace of copper, impossible to remove and weigh on account of the formation of a black deposit on the electrode.

suggests either that the Bordeaux copper is less effective per unit amount, or, more probably, that there was more of it present than was necessary.

It may be remarked here that determining and stating copper per dry weight of leaves may not mean quite as much as copper per given leaf area. However, the size and number of field samples required, and the magnitude of the differences obtained, make our method seem more suitable under the circumstances. If obliged to work on the leaf-area basis, one could eliminate the tedious measurements usually made with a planimeter, by means of a recently described cutting apparatus with automatic counter. (*16.*)

A study by Boyd in New York distinguishes several characteristics in regard to which dust can differ from spray, namely, distribution on the plants, retention by the plants, and adherence (or relatively permanent retention) to the plants. His study of the precipitation membranes (adhesive particles) of Bordeaux mixture and copper-lime dust indicated that "a more even distribution of the copper precipitate is possible with the spray than with the dust." (*2,* p. 8) Copper-carbonate dust applied to a wet surface gave no precipitation membranes. (*2,* p. 18.) Dust was more evenly distributed over dry leaves than over wet leaves but less of the discharged material was retained. When the dust applied to dry leaves was moistened suitably, it adhered somewhat better than that applied to wet leaves, probably due to the more uniform distribution of the material retained. However, under field conditions the dust retained by dry leaves was not wet suitably, so that more copper accumulated during the season when dust was applied on wet leaves than when applied on dry leaves. (*2,* p. 14-18.) The dust was less effective against diseases and insects when applied to dry foliage. (*2,* p. 63.)

Continuing his study further (in which he employed colorimetry) Boyd showed (*2,* p. 8-27) that with similar amounts of copper applied in Bordeaux mixture and copper-lime dust, sprayed copper adhered better than copper dusted onto wet leaves. Greenhouse tests and general observations in field experiments indicated that copper-lime dust possessed a higher degree of adhesiveness than a dry-Bordeaux preparation. Copper-carbonate dust, though retained as well as copper-lime dust, did not adhere as well. Kayso, a casein-lime spreader, had no appreciable effect on the adhesive-

ness of copper-lime dust or on the retention or adhesiveness of Bordeaux mixture, though it greatly increased the spreading qualities of the spray. Boyd concluded that per unit of leaf area, less copper in spray was required to insure protection against late blight than in copper-lime dust.

In New Jersey, 10-10-50 Bordeaux mixture when applied half as often as 5-5-50 was about equal or was inferior, in 1924 and 1925. (*34*; *37*.)

In Iowa in 1923, "the results of copper analyses of leaves sprayed with bordeaux mixture in control of potato-leaf hopper seems to indicate: first, that in general the self-prepared bordeaux mixture, 4-4-50 formula, adheres better to the foliage than do proprietary preparations of the mixture; second, that this higher percentage of adherence is slight under conditions in which there is considerable rainfall; third, that during dry periods self-prepared bordeaux was found to adhere very much better than the proprietary compounds; fourth, small amounts of either linseed oil or a casein preparation seemed to increase the sticking power of all bordeaux mixtures including the home-made as well as proprietary preparations." (*27*, p. 39-40).

In Switzerland, colloidal copper adheres better than Bordeaux and permits a reduction in copper content in some commercial preparations. (*44*, p. 509.)

EFFECT OF MISCELLANEOUS FACTORS ON LATE BLIGHT

MILD MOSAIC

While estimating percentages of foliage infected with late blight in 1927, it was noted that the plants having mosaic seemed to be the first to become infected. Some local growers were also of the opinion that the presence of mosaic increased the amount of late blight. In order to test these opinions, individual mosaic and healthy plants were examined on September 1 and the relative amounts of diseased foliage estimated. In all, 160 plants were recorded, 20 healthy and 20 mild mosaic for each of 4 treatments. The average percentage of foliage destroyed by the disease, given respectively for healthy and mosaic, was 3 and 5 for dust, 14 and

24 for Bordeaux mixture, 42 and 82 for colloidal copper, and 46 and 70 for the controls. Hence there was a consistent tendency for mild mosaic to increase susceptibility to late blight in Green Mountains.

The reason for this is not known. In general, mosaic plants are more prostrate in habit of growth and being closer to the moist soil would be subjected to more favorable conditions for spread of infection. The diseased plants also mature earlier and this may be correlated with disease susceptibility.

According to Dean, the freedom from disease in certified seed makes such seed easier to keep free from late blight by means of spraying. (*10*, p. 290.) Mosaic and other virus diseases are the kind most affected by certification.

Early Harvesting

In 1927, during late August and early September, many growers were harvesting their early potatoes for southern shipment. At that time most of the fields in Aroostook County were infected severely with late blight on the foliage. The atmosphere was moist and warm and ideal for general disease spread. On and about August 27, field observations were made through the important potato sections of the county. Most of the fields from Presque Isle to Houlton had been nearly defoliated by that time. Conditions were quite similar about Caribou, Presque Isle and Fort Fairfield. Digging was rather general. It was very evident that the tender and green tubers were readily inoculated when brushed and stirred with the diseased vines during the digging operation. On several occasions the harvested crop had been covered with blighted foliage and left in the field through a drizzling rain. One would expect that the water would wash the late-blight spores from potato vines and distribute them throughout the barrel of potatoes. Dr. Schultz, the resident Federal plant pathologist, often remarked that potatoes harvested under such conditions would decay before they reached their destination. It was shortly after these observations that growers and shippers complained that their car lots had rotted in transit.

Eventually an analysis was made of the official inspection reports. Such reports were received on 178 cars of Irish Cob-

blers and "round whites", 14 cars of Green Mountains, 6 cars of Bliss Triumphs, and on 66 cars of unknown variety. The results are summarized as follows:

	Sept. 1 to 16 incl.	Sept. 17 to Nov. 1 incl.
No. of cars reported	99	79
Ave. soft rot and Fusarium wet rot	26.3%	0.8%
Ave. late-blight rot	39.5%	2.5%
Ave. both preceding combined (not being separated in some reports)	66.2%	3.4%

September 16-17 was taken as a division point because on September 16 one report gave 40 per cent rot, and most reports up to that time gave high percentages, while over 5 per cent rot was uncommon after September 16.

The break at September 16-17 seems to be correlated with a combination of (1) death of Cobblers from several days' rapid progress of late blight about 10-14 days previously, this death being shown by our records and resulting in the exhaustion of live inoculum (late-blight spores) by about the middle of September; (2) low minimum temperature of 32° F. on September 14, supposed to have a chilling and injurious effect on the late-blight spores; (3) low mean temperature of 60 and below beginning on September 12, such low temperature being less favorable for the development of rots than the temperatures prevailing previously. The reports were charted according to source of stock but no correlation was apparent between the latitude of the locality and rot percentage.

When the late crop was harvested, rot was less prevalent than had been expected This probably was due in part to the fact that the foliage had long since died in most fields and thus the source of infection had been largely eliminated. In bin storage it was observed that more tuber rotting was experienced when the foliage had been kept partially green by spray but still had enough inoculum present to infect the tubers while being dug.

Soil Differences

The method of having a number of plots receiving the same treatment scattered about the field, and the plots of the several

treatments mixed together, has brought out more clearly than ever the effect of soil differences on disease, yield, and the benefits of spraying.

There also was a correlation, in 1927, between the amount of rot and soil factors. On Aroostook Farm our spray-test series had less than one per cent of the tubers rotted in any of the plots including those not sprayed. In another field which has a somewhat heavier soil, the rot was in 33 per cent of the crop in the unsprayed plots. Here dusted and sprayed plots had from 3 to 4 per cent of the tubers rotted when dug.

One field evidently was most favored for the development of foliage blight. It has a wet soil and was the only place where spraying with Bordeaux mixture did not give good control. When dug, however, the amount of tuber rot was of little importance, which was contrary to our expectations.

In New York, soil type is an important factor in its effect on loss from late-blight rot. (*21*, p. 7.) In New Hampshire it was noted in one test that "most of the rotten tubers found were in those parts of the field in which the grower was troubled with rather a heavy growth of witch grass." (*46*, p. 31.)

In Switzerland, tuber infection with late blight was reported to be greater in heavier than in light soils (*44*, p. 506, 509) with the explanation on the basis of the foliage being longer-lived and furnishing more inoculum at harvest, and of the conditions being damper in the ground and in the first part of storage. Tuber immaturity would be involved, also.

With reference to late blight in Holland, "among potato growers it is a very well-known fact that soil differences may influence the percentage of diseased tubers in the crop," sandy soil generally giving no tuber infection even when the foliage is as severely diseased as in clay soil. A study of this problem in Holland showed that the difference depends to some extent on the effect of soil conditions on the structure of the developing tubers, due largely to a lack of cork substance in clay-grown tubers. (*28*; *29*, p. 176.)

COMMERCIAL SPRAYING AND DUSTING

In 1927, during the period of rapid late-blight spread, discussions were general among the growers as to the relative merits of

dust and spray. Some growers made weekly visits to the spray plots on Aroostook Farm. As a result of these discussions and the interest shown, some commercial fields were examined by one of the writers (Bonde). This was done on August 26 and 27 south of Presque Isle in the vicinity of Mars Hill and Littleton. At that time the fields in general were badly blighted.

The field observations indicate that late blight was well checked and caused little damage if either a copper dust or Bordeaux spray had been used properly. From the limited number of observations made, it was not possible to determine a difference in the fungicidal value of the various commercial brands of dust used. Some evident reasons for the general lack of foliage late-blight control were noted in the order of decreasing importance, as follows: (1) Applications were discontinued too early in the season. (2) Many growers did not commence to spray until the infection was general in their fields. (3) There was also carelessness regarding the preparation of the spray materials. (4) There are still many inefficient sprayer machines in use. While location and soil may influence the results, the problem of difference in commercial control is involved largely with the inequality of growers in adapting their methods to the seasonal requirements. This inequality perhaps may be reduced by developing a simpler method than that of using Bordeaux mixture, or even by a system of official spray warnings given when late blight is first found.

Stuart, who has probably observed potato growing more extensively than any one else in this country, thinks that "too frequently growers have ceased spraying before it was really safe and as a result have in many instances suffered heavy losses through late blight infection of the tubers." (*56.*)

In New Hampshire in commercial fields in the few cases where dusting was practised, "no material differences in yield appeared as compared with wet Bordeaux sprays." (*49*, p. 22.)

In New York, spray rings served to overcome the handicaps of individual spraying, such as poor equipment, neglect through pressure of other kinds of farm work, expense of buying adequate equipment, cost and unavailability of good materials, and indifference which results from not understanding the possibility and manner of securing gains. Each sprayer kept from 50 to 83 acres covered. *(42.)*

In Florida in 1925, an economic survey showed consistently better yields, in different size classes of farms, where dusting was practised, as against no dusting. (*40*, p. 218.)

In Prince Edward Island "in some seasons it would appear as if the best-made Bordeaux mixture is not as effective as might be expected" against early blight. (*18*, p. 27.)

In Bermuda, dusting is advised in preference to spraying, the agricultural experiment station renting both hand machines and horse-drawn traction machines for the purpose. *(9.)* There the smallness of the farms and of the total area of the colony makes such help not only feasible but desirable.

COSTS AND PROFITS OF USING FUNGICIDES

In a previous section of this bulletin it was pointed out that under conditions like those of the experimental tests a grower could reasonably expect the cost of spraying to be balanced if it were equal to the income from 9 additional barrels or 26 bushels of field-run crop. With this in mind, and with the viewpoint, also defined in the same section, that a potato grower should always apply fungicides so that he will be sure of protection in the worst seasons, it is of interest to compare the costs of different kinds of fungicides.

An analysis of costs, including materials, interest, depreciation, repairs, and labor, made in our last bulletin (*15*, p. 245, 272) gave $11.07 as the total cost of spraying one acre for one season and $15.81 as that of copper-equivalent dusting with 20-80 copper-lime material. In 1928, with late blight severe and several kinds of materials about equally valuable for controlling that disease and increasing the yield, a similar cost analysis gives about $11 for homemade Bordeaux mixture, about $19 for 25-75 copper-lime dust, about $22 for dried Bordeaux applied as spray, and about $23 for the last applied as dust. In order to cost about the same as the homemade Bordeaux, colloidal copper at the strength used would have to be available at about seven cents a pound; it is still in the experimental stage and not available commercially.

With gross receipts 70 cents a bushel (80 cents less 10 cents for picking and selling), the average expected gain of 26 bushels would amount to about $18, which would justify the use of some materials but not of all. Of course the actual gain would vary

with the season and other conditions, the effect of soil on rot being especially variable. This variability makes the problem of how to use fungicides most profitably, more or less one for the individual grower to solve for himself.

In New Hampshire in 1923-26, with metallic copper per acre equivalent and both applied by hand, 8-4-50 Bordeaux mixture was somewhat cheaper than a 10-per cent copper-lime dust. (*5*, p. 12.) Dust cost $2.85 per acre application on 9 farms while the corresponding spraying cost was $2.30 on 12 farms. (*50.*)

In New York with spray rings costing from $5.65 to $11.00 per acre, the latter including the cost of the sprayer during the first year of use, the gain has averaged about $43 an acre on 840 acres without considering premiums for reliability or losses in storage. *(42.)* Such spraying as described by another *(13)* with some labor omitted, figures out at about $10 for 1926 and $9 for 1927, per acre for the season. In New Jersey in 1926 on three 300-bushel (per acre) farms, spraying costs were about $6.00 an acre. (*38*, p. 17.) A summary of the results of spray rings as an extension project, suggests that spraying costs are about $9 or $10 an acre in New Jersey and about $11 or $12 in New York. A group sprayer operated by the farmers, each spraying his own acreage, has much higher repair bills than when a single operator is employed. (*41*, p. 8.)

In Pennsylvania in the six years 1920-25, an average yield increase of from 60 to 80 bushels a year was secured in some 1700 demonstrations at an average cost of about $11.00 an acre. *(51.)*

In Ohio, fresh-mixed dust costs slightly more than Bordeaux spray and much less than commercial dusts. *(59.)*

In Michigan the cost of material and its application was about half as much again for dust as for spray. *(43.)* In Wisconsin in 1922-25 tests, four applications of spray cost $11.26 and of dust cost $11.97. (*11*, p. 15.)

In New Brunswick in 1925, the cost of one application was $2.21 for 20-80 copper-lime dust and $1.78 for 4-4-40 (4-4-50, U. S. A. gals.) Bordeaux mixture. (*1*, p. 34-35.)

GENERAL USE OF THE EXPERIMENTAL DATA

Experimental tests give accurate comparisons that show what can happen and that lead to a reasonable explanation of some

growers' results. However, experiments can not serve to tell every potato grower in the State of Maine just what he will gain from spraying or dusting on his own farm. This is because many conditions influence the results and because at present only a few of these conditions can be measured easily or have been studied carefully. Fernow, giving a review of some of the literature, states his belief that it will not be possible to learn definitely how much increase in yield, and how much cost per given increase, is to be expected, because of the great variability in conditions. *(13.)* The known influential conditions include kind of material, strength of material, amount of material, time of application, use of vine protector, kind of disease or pest, amount of disease or pest, kind of machine, condition of machine, skill in use of machine, variety of potato, kind of season, time of killing fall frost, location, type of soil, time of digging, and kind of storage. Some of these conditions have been discussed in the preceding pages with special reference to Aroostook County.

This leads one again, as did the discussion in the preceding section of this bulletin, to the conclusion that the problem is to some extent one for the individual grower to solve. In doing his part he should have the preceding ideas in mind regarding the possible effects of various conditions, so that he will not make up his mind too soon. It might be still better if in solving his own problem he should have the help of an expert who has the various possibilities in mind, supplemented by some idea of probabilities gained from the careful observation of a large number of commercial fields.

Some suggestions for growers' tests have been given in a previous publication (*15*, p. 265) and some can be obtained by inquiry of the Extension Service. A selection of extracts showing typical extension methods employed and results obtained in potato spraying in a number of States, is available. *(41)*

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